IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

The efficiency analysis of a 300 MW steam turbine unit after the through-flow transformation of based on thermal performance test method

The efficiency analysis of a 300 MW steam turbine unit after the through-flow transformation of based on thermal performance test method

B Wang[1,2] and Y Z Zhao[1]

[1]Steam Turbine and Gas Turbine Technical Department, Huadian Electric Power Research Institute, Hangzhou 310030, Zhejiang Province, China

E-mail: 458612891@qq.com/bo-wang@chder.com

Abstract. In this paper, the thermal performance of a 300 MW subcritical steam turbine is studied. The influence of the flow remoulding technology on the heat dissipation rate is analyzed by comparing the thermal performance test data before and after the transformation and after the completion of the operation. It focuses on the reasons for the decline in thermal performance after four-year operation. Through the transformation of the flow remoulding can greatly enhance the efficiency of the steam turbine, the gap between the steam seal and cylinder defect are the main reasons for the decrease of the thermal performance of the steam turbine after four years of operation. After four years of operation, the efficiency of the steam turbine is still superior to that before the flow.

1. Introduction

At present, most of the 300 MW sub-critical units in China are based on the Westinghouse technology introduced in the 1980s, after continuous optimization, such 300 MW sub-critical units designed and manufactured generally have low flow efficiency and high heat consumption [1,2]. After nearly 30 years of development, China Eastern electric co., Shanghai electric co., and Harbin electric co., ltd. We have witnessed rapid development of domestically produced technology. Used steam turbine manufacturer with complete 3d aerodynamic optimization design technology to flow field design [3], linear velocity distribution rationalization, separation phenomenon is effectively suppressed, improving traditional seal design technology at the same time, adjust the seal clearance, effectively reduce the seal leakage loss [4-6]. After the through-flow transformation, the heat consumption rate of the unit decreases and the output force increases, which has obvious economic, social and environmental benefits. In this paper, the thermal performance test data of a 300 MW unit before and after the through-flow transformation are compared to analyze the influence of the technology on the heat consumption rate. The reasons for the decrease of thermal performance of steam turbine are analyzed in order to provide reference for the guarantee of thermal consumption of similar units after modification.

The thermal cycle of the object studied in this paper is as follows: new steam produced by the boiler (pressure 16.67 MPa, temperature 535°C) is into the high-pressure cylinder of the steam turbine to do work, the steam is discharged to the reheater of the boiler and then was heated to the intermediate-pressure cylinder of the turbine to do work. The exhaust steam of the intermediate-pressure cylinder was into the low-pressure cylinder to do work, the steam is discharged to the condenser.

2. Thermal performance test data before and after the through-flow transformation

The steam turbine unit studied in this paper is the type N300-16.7/537/537 unit produced by dong-fang steam turbine co, LTD, which was put into commercial operation in 1999. In 2010, the model was changed to C330-16.67/537/537 after the through-flow transformation. Table 1 shows the test data of thermal performance of steam turbine before and after the flow transformation. It can be found from table 1 that the heat consumption rate after the second type of modification before the ventilation modification is 8516.0 kJ/(kW·h), which is higher than the design value of 531.0 kJ/(kW·h). This paper further verifies the viewpoint proposed in literature [1] that "the early 300MW rated unit with transport has low efficiency of ventilation and high coal consumption". The heat consumption rate was reduced to 7939.1 kJ/(kW·h) after the through-flow modification. The thermal performance of the steam turbine was greatly improved by reducing the heat consumption rate by 576.9 kJ/(kW·h).

Table 1. Experimental data of thermal performance before and after flow modification.

Working condition	unit	Before modification		After modification	
		design	3VWO	design	3VWO
Load	MW	300.0	298.8	330.0	328.5
Main steam pressure	MPa	16.7	15.7	16.7	16.7
Main steam temperature	°C	537.0	536.2	537.0	532.3
High pressure cylinder exhaust pressure	MPa	3.6	3.8	3.7	3.6
High pressure cylinder exhaust steam temperature	°C	318.6	342.4	320.5	312.9
High pressure cylinder efficiency	%	84.9	79.7	85.8	85.9
Reheat steam pressure	MPa	3.2	3.5	3.3	3.2
The temperature of the reheated steam	°C	537.0	528.4	537.0	534.6
Medium pressure cylinder exhaust pressure	MPa	0.8	0.8	0.8	0.8
Medium pressure cylinder exhaust steam temperature	°C	337.4	328.8	336.3	335.2
Intermediate cylinder efficiency	%	91.6	89.5	92.2	91.8
Low pressure cylinder inlet pressure	MPa	0.8	0.8	0.8	0.7
Low pressure cylinder inlet temperature	°C	337.4	328.8	336.3	331.0
Exhaust steam pressure	kPa	4.9	7.6	5.4	5.8
UEEP low pressure cylinder efficiency	%	87.8	81.0	90.3	90.2
Test heat rate	kJ/(kW·h)	7985.0	8664.1	7895.0	7968.1
The second type of modified heat consumption rate	kJ/(kW·h)	7985.0	8516.0	7895.0	7939.1

3. The reasons of unit performance degradation

Table 2 shows the thermal performance test data after the through-flow modification after four years of operation. It can be seen from table 2 that the performance of the unit decreases, with the efficiency of high, medium and low-pressure cylinders decreasing by 2.3, 1.5 and 2.9 percentage points respectively, and the heat consumption rate of the second type of unit increases by 242.3 kJ/(kW·h) after modification.

IOP Conf. Series: Earth and Environmental Science **188** (2018) 012092 doi:10.1088/1755-1315/188/1/012092

Table 2. Performance test data after four years' operation and modification of through-flow.

Working condition	unit	After modification	After modification	After 4 years of operation
		design	3VWO	3VWO
Load	MW	330.0	328.5	320.0
Main steam pressure	MPa	16.7	16.7	15.1
Main steam temperature	ºC	537.0	532.3	530.6
High pressure cylinder exhaust pressure	MPa	3.7	3.6	3.5
High pressure cylinder exhaust steam temperature	ºC	320.5	312.9	327.2
High pressure cylinder efficiency	%	85.8	85.9	83.6
Reheat steam pressure	MPa	3.3	3.2	3.2
The temperature of the reheated steam	ºC	537.0	534.6	534.2
Medium pressure cylinder exhaust pressure	MPa	0.8	0.8	0.8
Medium pressure cylinder exhaust steam temperature	ºC	336.3	335.2	331.9
Intermediate cylinder efficiency	%	92.2	91.8	90.3
Low pressure cylinder inlet pressure	MPa	0.8	0.8	0.8
Low pressure cylinder inlet temperature	ºC	336.3	334.1	331.0
Exhaust steam pressure	kPa	5.4	5.8	4.1
UEEP low pressure cylinder efficiency	%	90.3	90.2	87.3
Test heat rate	kJ/(kW·h)	7895.0	7968.1	8208.8
The second type of modified heat consumption rate	kJ/(kW·h)	7895.0	7939.1	8181.4

For every one percentage point reduction in the efficiency of high, medium and low pressure cylinders of 300 MW sub-critical unit, the corresponding experience value of thermal consumption increase [7] is 34.6, 33.2 and 97.5 kJ/(kW·h), respectively. Therefore, the reduction of high, medium and low-pressure cylinder efficiency led to an increase in heat consumption of 165.3 kJ/(kW·h), and the reduction of three-cylinder efficiency was the main reason for the increase of heat consumption and efficiency decline of the steam turbine unit. Therefore, this paper mainly analyzes the reasons leading to the decrease of the efficiency of three cylinders.

The clearance of steam seal increases. Table 3 shows the excess clearance data of partial steam seals measured by cylinder stripping inspection after 4 years' operation of the steam turbine. The clearance of steam seal is adjusted to the lower limit of the standard value after the reform of flow-through. After 4 years of operation, most of the clearance of steam seal has exceeded the standard value. Excessive clearance of steam seal is an important factor to reduce the efficiency of high, medium and low pressure cylinders.

Figures 1-3 are defects in the cylinder. As shown in figure 1, there is steam leakage at the joint surface of high and medium pressure cylinder, High pressure steam is leaked directly from high pressure cylinder to low pressure area. This part of the steam does not do any work in the turbine, so it will cause energy loss.

Table 3. Partial seal clearance.

Level	Measuring position	Standard values (mm)	Measured value (mm)	
			0°	90°
The first level	A	6.41~6.89	7.70	7.20
	D2	1.4~1.675	2.05	2.00
High pressure level 2	D	0.9~1.3	2.10	2.00
	E	0.8~1.25	1.80	1.85
High pressure level 3	D	0.9~1.3	2.10	2.05
	E	0.8~1.25	2.00	1.45
	F	0.9~1.3	1.90	1.85
Medium voltage level 2	D	0.9~1.30	1.80	1.85
	F	0.9~1.30	1.90	1.70
Medium pressure level 6	A	5.35~6.69	7.50	7.20
	B	5.09~7.93	8.90	8.80
Low pressure forward to level 1	C	1.35~1.85	2.30	4.00
	L	1.65~2.2	2.65	3.65

Figure 1. Cylinder steam leakage surface.

As shown in figure 2, the steam seal teeth of the semi-steam seal ring on the front of the third-stage partition of the low-pressure cylinder are fractured, leading to increased leakage loss of the steam turbine.

As shown in figure 3, the stator blade of the 1st stage of medium pressure is deformed, which will lead to the steam flow field disorder, impact loss, impeller friction loss and unit efficiency reduction.

Figure 2. Steam seal tooth fracture.

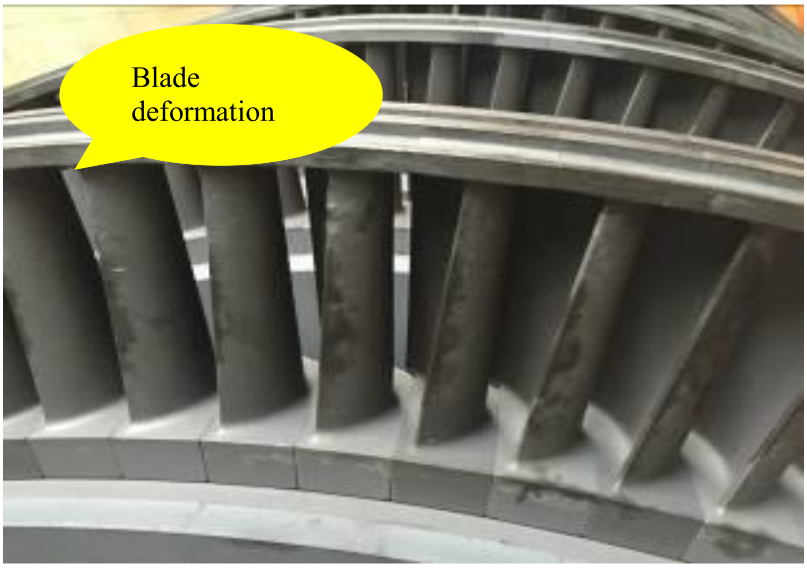

Figure 3. Blade deformation.

4. Conclusions

After four years' operation, the efficiency of steam turbine unit is still better than that before the reform. The through-flow reform of steam turbine can greatly improve the efficiency of service 300 MW sub-critical steam turbine. The increase of seal clearance and cylinder defects will lead to the reduction of thermal performance of steam turbine after the modification of the flow. Through the transformation of the flow remoulding can greatly enhance the economic efficiency of the steam turbine, the gap between the steam seal and cylinder defect are the main reasons for the decrease of the thermal performance of the steam turbine after four years of operation. After four years of operation, the efficiency of the steam turbine is still superior to that before the flow.

Acknowledgments
This research was financially supported by my colleagues, are greatly acknowledged.

IOP Conf. Series: Earth and Environmental Science **188** (2018) 012092 doi:10.1088/1755-1315/188/1/012092

References

[1] Zhao J, Zhu L T, Fu C and Yang S M 2011 General description of the transformation of the pass-through part of 300 MW steam turbine *The Heating Power Turbine* **40** 39-42

[2] Zhu X L and Song W X 1999 Problems and solutions of domestic imported 300 MW steam turbine unit *Therm. Power Gener*. **1999** 12-5

[3] Yuan X, Lin Z R, Lai Y Y and Chen Z P 2004 Turbine blade pneumatic optimization design system *The Heating Power Turbine* **33** 8-13+22

[4] Cao L H 2012 Numerical analysis of steam turbine flow and study on thermal economy diagnosis methods (Beijing: North China Electric Power University) p 84

[5] Zhou Y L, Cao L H and Tu W 2010 The influence of the change of turbine clearance on relative internal efficiency and power *Therm. Power Gener*. **39** 12-5

[6] Chu W 2006 Application of brenden seal on 300 MW steam turbine (Chongqing University) pp 5-8

[7] Li Q, Zhang X Y and Xu G Z 2007 *Manual for Management of Production Index of Thermal Power Plant* (Beijing: China Electric Power Press) pp 279-81